HIGHWAY SAFETY IMPROVEMENT PROGRAM
INDIANA "5 PERCENT REPORT"

This report is to meet the requirement for Indiana to submit an annual report describing not less than 5 percent of their highway locations exhibiting the most severe safety needs. The intent of the report is to raise the public awareness of the highway safety needs and the challenges that exist.

Extent of Coverage

The crashes used for this report are for the calendar years of 2003, 2004 and 2005 obtained from the Indiana State Police. The extent of coverage is for Interstate, US and State Roads, those administered by INDOT. The only intersections included are those at intersections of INDOT to INDOT administered roads. The report does not include local roads.

The crash records were assigned first to some 1085 intersections if the crash fell within 250 feet of the intersection. The remaining crashes were assigned to segments of which there were 19,262.

Fatal and injury crashes were combined and assigned. All injury crashes were used since at this time serious injury crashes are difficult to distinguish.

Explanation and an Estimated Schedule of when Full Coverage will be Reported

The present report is based on the approximate 11,700 miles of INDOT administered network and does not include local roads. There was not time to develop a complete road network. An investigation will be made to determine what road networks are available. The state wide transportation model does contain a road network of approximately 30,000 miles which will be considered. It is also a possibility that the state and local road inventory network could be used which would give 100% coverage. At any rate next years report will be expanded considerably.

Approximately 80% of the crashes had sufficient information that they could be matched to an intersection or road segment. Processes being developed will improve on the number of crashes that can be assigned.

Methodology Used to Determine 5% most Hazardous Locations

For each intersection and road segment five measures of safety and evaluation criteria were calculated. These are the fatal-injury Annual Crash Frequency, fatal-injury Annual Crash Density, fatal-injury Crash Rate, fatal-injury Index of Crash Frequency and the fatal-injury Index of Crash Cost.

Appendix B contains a Working Report that explains these measures in detail and the procedures used to produce them.

Because the index of crash costs represents a measure of the impact that crashes have on society it was chosen as the factor to determine Indiana's segments and intersections that exhibit the most severe safety needs. Those intersections and segments that had 4.0 standard deviations more crash cost than could be expected were chosen. The number of fatal and injury crashes for these selected intersections and road segments were then summed. It was found that they represent approximately 7.2 percent of the fatal-injury crashes for 2003 through 2005. Therefore these intersections and roadway segments represent more then the minimum requested.

There were 93 roadway segments selected out of the 19,262 roadway segments analyzed and 11 intersections out of 1,085. This shows that 0.51% of the segments and intersections analyzed accounted for 7.2% of the fatal-injury crashes.

A listing of the intersections and road segments can be found in appendix A.

Assessment of Potential Remedies, their Estimated Costs, and Impediments to their Implementation

Detailed improvement remedies and costs are currently not available for each segment or intersection. Each road segment and intersection was compared to projects either planned or under construction. Under the potential remedy column an "A" indicates that the road segment or intersection needs to be reviewed, an "X" means that a project presently exists that will mitigate the safety need. There were several locations where projects are scheduled but since the project does not necessarily mitigate the safety need an "A" was assigned and the safety need will be reviewed. Included in the table are Project Designation numbers (DES#), improvement type and the estimated cost. Projects that are already planned will be reviewed to see if the proposed project can incorporate mitigation of the safety need.

Approximately 30 of the severe safety need locations have projects planned that will mitigate the safety need. Another 74 locations did not and will be evaluated and programmed for future project if practical.

The above mentioned listing will be shared with the districts for consideration in the next call for projects and as projects develop, the costs and remedies will be included in the annual "5 percent report".

Working Report to Assist INDOT
In Preparation of the 5-percent Report for 2006
REVISED September 8, 2006

Andrew Tarko
August 13, 2006

INTRODUCTION

This working report summarizes the data and measures of safety used to develop lists of segments and intersections in Indiana included in the attached Excel file. This report is meant to help the Indiana Department of Transportation write the 5% report requested by FHWA.

DATA

The data used to develop the lists include: crash data, segment data, and intersection data. The crash data has been extracted from the Indiana State Police Crash Database. The source files are in the text format and include records of all crashes reported on public roads in Indiana in the period of 2003-2005.

The segment data were in the format of a dbf table. It is a part of he Indiana Travel Demand Model and it includes all the segments administered by the Indiana Department of Transportation. These segment data were extracted by INDOT from the Indiana Roadway Inventory Database, supplemented with geographic coordinates and other data, and converted to the dbf format required by the TransCAD. The recent Annual Average Daily Traffic values were included in the segment table.

The intersection data also takes the form of a dbf table and it has been generated with the tool called INSIP (INput to Safety In Planning tool) developed by the Purdue University research team. The segment data were used to identify all the network nodes where at least three state road segments meet. The table of state network nodes includes location, traffic, and geometry data extracted from the road segment table and converted as needed.

The data currently available allow analyzing road segments and intersections administered by INDOT. Inclusion of local roads will be considered for the next year 5% report.

METHOD

The procedure of ranking road locations by level of hazard requires crashes assigned to these locations and proper measures of the safety level.

Assigning crashes to the road network

The crashes reported during the three-year period 2003-2005 obtained from the Indiana State Police were assigned to the Indiana network using the INSIP tool. The original text files were reformatted to fit the TransCAD requirements. A total of 16 tables were created from which the tables consisted of type 10 records were further used. This record type includes all the information needed for the analysis: GIS coordinates of most crashes (app. 80%), names of the streets, time, date, and severity of crashes. In the first step, the INSIP assigned crashes to network nodes based on the geographical proximity. The 250 feet criterion was used according to which any crash that occurred on a road within 250 feet from the center of an intersection is assigned to that intersection. In the next step, the remaining crashes are assigned to the nearest road segments. The outcome of this procedure is the crashes assigned to segments and intersections counted by year and severity. The obtained counts have been attached to the original interaction and segment tables.

The crash assignment procedure also generates a set of tables that link the crash records, with segment and intersection records. They allow checking the detail information about the crashes assigned to specific segments and intersections. These tables were used to verify the correctness of the crash assignment results by displaying on a TransCAD map the crashes assigned to several selected segments and intersections. The check has confirmed good quality of the assignment.

Measures of Safety and Evaluation Criteria

Locations can be ranked (sorted) from two general points of view:

(1) System wide perspective, and
(2) Individual user perspective.

The systems perspective aims to reduce as many crashes as practical in the studied area and to promote the most cost-effective mitigation of hazard. The user perspective aims to reduce the excessive risk faced by individual users, which promotes fairness of the highway system by reducing the difference between risks faced by users at different locations. These two perspectives yield different rank lists.

Annual crash frequency is a system perspective criterion used for intersections. It is a basic measure of crash experience and easy to use as it requires only crash data. The crash frequency is estimated by dividing the number of crashes by the number of years. Selecting locations with a high crash frequency does not consider exposure to risk, i.e. does not take into account volume or vehicle miles traveled (VMT).

Annual crash density is a system perspective criterion used for segments. It provides the normalized annual crash frequency on segments and it is expressed in number of crashes per mile per year.

Crash rate is a user perspective criterion. It is the number of crashes divided by the amount of exposure to risk at the location. For an intersection, a crash rate is calculated as the annual number of crashes per million vehicles entering the intersection. For a roadway segment, a crash rate is calculated as the annual number of crashes per million vehicle-miles traveled (VMT).

Neither a crash frequency nor a crash rate considers uncertainty caused by random variability in the annual number of crashes. Consequently, a high value of crash frequency or crash rate may be caused by randomness and not by high hazard. To incorporate consideration of random crash variability, an index of crash frequency and the index of crash cost are calculated.

Index of crash frequency (I_{CF}) measures the difference between expected and reported number of crashes divided by the standard deviation of the difference estimate. It combines the system and user perspectives with a stronger emphasis on the system perspective. For example, I_{CF} = 2 indicates that the number of crashes at the location exceeds the expected number of crashes for that location by two standard deviations. A set of predictive equations is presented Table 1. These equations have been developed for this analysis by fitting the 2003-2005 total crash counts to the segment and intersection data (segment lengths and traffic volumes). Index of crash frequency was calculated using Equation 1.

$$I_{CF} = \frac{A - a \times Y}{\sqrt{A + a^2 \times Y^2 \times D}} \qquad \text{Equation 1}$$

where :
A = number of crashes during Y years (three years here),
a = typical crash frequency calculated using Table 1,
Y = number of years in analyzed period, in years, and
D = over-dispersion parameter taken from Table 1. The smaller factor, the better crash frequency estimate a.

The index of crash frequency can be used in two different ways. In the first method, locations can be ranked using the index of crash frequency. The sorted locations form a priority list for safety reviews, starting with the location for which the evidence of a high crash location is strongest. In the second method, locations can be sorted by other criteria and then the only ones from the top of the list and statistically significant (let say, I_{CF} >2 are selected.

Index of crash cost (I_{CC}) measures the difference between expected and estimated crash cost at the location divided by the standard deviation of the difference. It incorporates the crash severity and combines the system and user perspectives with a stronger emphasis on the system perspective. For example, I_{CC} =2 implies that the crash cost at the location exceeds the expected crash cost for that location by two standard deviations. A set of predictive equations developed for this study by fitting the counts of injury/fatal and PDO

crashes to the segment and intersection data are presented in Table 2. Index of crash cost is calculated using Equation 2.

$$I_{CC} = \frac{C_{PD}(PD - Y \times a_{PD}) + C_{IF}(IF - Y \times a_{IF})}{\sqrt{(C_{PD}^2 \times PD + C_{IF}^2 \times IF + C_{PD}^2 \times Y^2 \times a_{PD}{}^2 \times D_{PD} + C_{IF}^2 \times Y^2 \times a_{IF}{}^2 \times D_{IF})}} \quad \text{Equation 2}$$

where:
C_{PD} = average cost of PDO crash, here $6,500,
C_{IF} = average cost of I/F crash, here $65,000,
PD = number of PDO crashes during Y years,
IF = number of I/F crashes during Y years,
a_{PD} = typical PDO crash frequency, in PDO crashes per year,
a_{IF} = typical I/F crash frequency, in, I/F crashes per year,
Y = number of years in analyzed period, in years,
D_{PD} = over-dispersion parameter for PDO crashes, and
D_{IF} = over-dispersion parameter for I/F crashes.

RESULTS

The Excel file provided with this report includes an Intersection spreadsheet with 1085 intersections and a Segments spreadsheet with 19,262 inventory segments. The color-coded columns have names that are self-explaining or explained in the above part of this report. The blue color indicates location and ID information needed to display the results on an electronic GIS map or to find the segment or intersection on a map. The yellow color indicates all the input values used to calculate the results. The orange color indicates the results. The remaining white columns contain wealth of additional information about segments and intersections. The variable (column) names for segments are explained in the manual for the Travel Demand Model. The variable (column) names for intersections are in the draft final report for the JTRP project on safety-conscious planning. These descriptions can be provided upon request if needed.

The tables can be sorted by any of the columns containing measures of safety as introduced in the previous section of the report. Other can serve as secondary measures. If using measures other than Index of Crash Frequency and Index of Crash Cost, then the segment and intersection lists have to be kept apart and sorted individually. The value of the Indices of Crash Frequency and Cost give an indication of the statistical significance that a location experiences excessive hazard.

Another alternative is to combine the segment and intersection lists and sort the combined list by Index of Crash Cost. Other measures such as crash rate can be used to make a final selection.

In any case, the segments that are too short may be removed.

Table 1 Safety performance functions

Facility	**Safety Performance Functions**	**Over-dispersion parameter (*D*)**
Intersections	$a = 3.17 \cdot Q_1^{0.403} \times Q_2^{0.416}$	0.460
Rural non-interstate segments	$a = 2.291 \times L \times Q^{0.809}$	0.430
Rural interstate segments	$a = 0.557 \times L \times Q^{0.978}$	0.086
Urban non-interstate segments	$a = 4.747 \times L \times Q^{0.860}$	0.893
Urban interstate segments	$a = 0.230 \times L \times Q^{1.350}$	0.225
a = typical crash frequency in Indiana , in crashes per year, Q = AADT entering the intersection or along the road segment, in thousand vehicles per day, D = over-dispersion parameter, and L = road segment length, in miles.		

Table 2 Safety performance functions including severity

Facility	**Safety Performance Functions**	**Over-dispersion parameter**
Intersections	$a_{IF} = 0.913 \cdot Q_1^{0.271} \cdot Q_2^{0.456}$	0.257
	$a_{PDO} = 2.38 \cdot Q_1^{0.415} \cdot Q_2^{0.421}$	0.434
Rural non-interstate segments	$a_{IF} = 0.462 \times L \times Q^{0.825}$	0.120
	$a_{PD} = 1.747 \times L \times Q^{0.793}$	0.370
Rural interstate segments	$a_{IF} = 0.065 \times L \times Q^{1.096}$	0.005
	$a_{PD} = 0.506 \times L \times Q^{0.950}$	0.082
Urban non-interstate segments	$a_{IF} = 0.959 \times L \times Q^{0.886}$	0.565
	$a_{PD} = 3.394 \times L \times Q^{0.870}$	0.863
Urban interstate segments	$a_{IF} = 0.913 \times L \times Q^{0.456}$	0.257
	$a_{PD} = 0.181 \times L \times Q^{1.358}$	0.218
a_{PD} = typical PDO crash frequency, in PDO crashes per year, a_{IF} = typical I/F crash frequency, in I/F crashes per year, Q = AADT entering an intersection or along the road segment, in thousand veh/day, L = road segment length, in miles, and D = over-dispersion parameter.		

CLOSURE

The present report does not include local roads due to the lack of sufficiently complete representation of Indiana road network. A progress is being made to include local roads. An effort is planned to incorporate local roads in the next year report. Another issue that needs to be addressed is the frequent lack of data for local roads. It may require modification of the method used this year.